5-30-2014

Using GIS to Predict Areas of Cultural Resources Within the Walnut Canyon Study Area near Flagstaff, Arizona

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Recommended Citation

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Document Type

Masters Capstone Project

Degree Name

M.S. in Geographic Information Science

Department

Geography

Keywords

Cultural resources, Walnut Canyon, Flagstaff, Arizona, Geostatistical and spatial analysis techniques of directional distribution

Subject Categories

Geographic Information Sciences | Geography | Social and Behavioral Sciences | Spatial Science

Comments

Publication Statement

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Introduction

Park planning in the National Park Service (NPS) aims to make sure that decisions made are as effective and efficient as possible in carrying out the NPS Mission. Cultural resources impose a unique aspect to park planning due to its importance of stories they tell of the past and by helping us understand the world and our place in it. There are various perspectives to understanding earlier populations by knowing the history associated with them during that time as well as interpretations by archaeologists of structures and artifacts that remain in the present day. Learning history by examining cultural resources can help answer questions such as, what did people of that time eat, was there any type of trade amongst others, how did the society function, and what were their beliefs from a social aspect?

Walnut Canyon National Monument (WACA) located near Flagstaff, Arizona, (see Figure 1 below) embodies an area filled with human history. The canyon rim elevation is around 7,000 feet and contains numerous cliff dwellings constructed by the Sinagua, a cultural group named by archaeologists from the old Spanish name, Sierra de Sin Agua, or "mountains without water" (National Park Service 2014). According to the National Park Service, the first permanent inhabitants flourished the region from about A.D. 600 until 1400. It is unknown as to why the Sinagua disappeared, but it is thought to be from major drought or fear of neighboring tribes. Centuries later, families farmed near and around the

canyon rim growing corn, squash, and beans and had to strategically plan the location of their farms due to sparse water sources. Cultural resources left behind during these times are what help us understand the past. Identifying, recording, and protecting these resources will continue to keep the story alive for generations to follow.
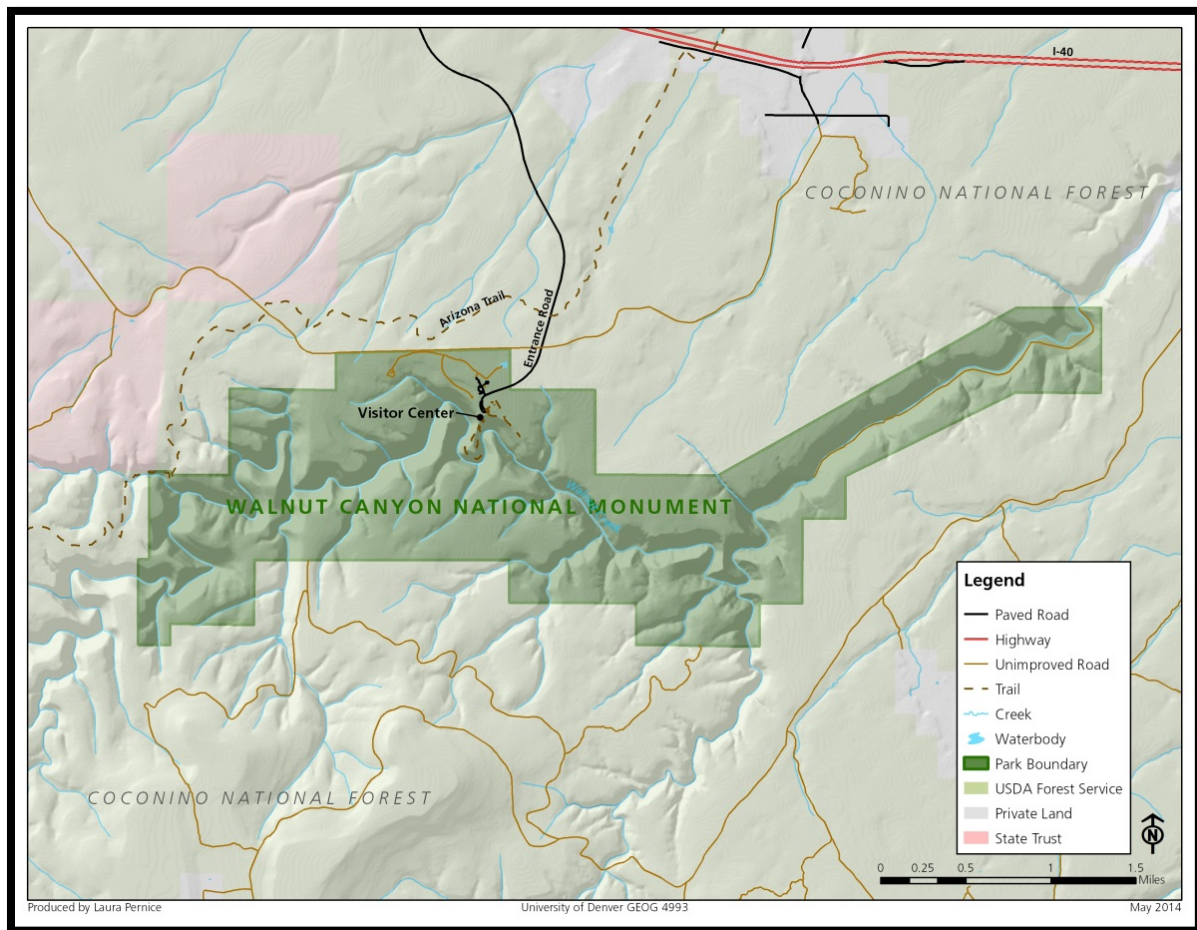
Figure 1. Walnut Canyon National Monument

The Need for a Predictive Model for Cultural Resource Sites

Walnut Canyon National Monument is a special place because of the land being preserved and protected by the National Park Service. There is a need to continue the stories of the past that goes beyond the park boundary

as well as a need to evaluate the national significance of the Walnut Canyon Study Area. Under The Omnibus Public Land Management Act of 2009, the NPS in collaboration with the U.S. Forest Service were directed to explore management options for the Walnut Canyon Study Area that encompasses around 28,000 acres of land surrounding WACA. The Walnut Canyon Special Study report which was prepared by the National Park Service, U.S. Forest Service, and the City of Flagstaff and Coconino County, proposed three different management options which included:

- Suitability and feasibility of designating all or part of the study area to Walnut Canyon National Monument.

- Continued management of the study area by the U.S. Forest Service.

- Any other designation or management option that would provide for (1) protection of resources within the study area; and (2) continued access to, and use of, the study area by the public.

Predicting where cultural resources exist within the Walnut Canyon Study Area is an imperative element that influences management decision and land use planning in relation to any of the three management options that were previously mentioned.
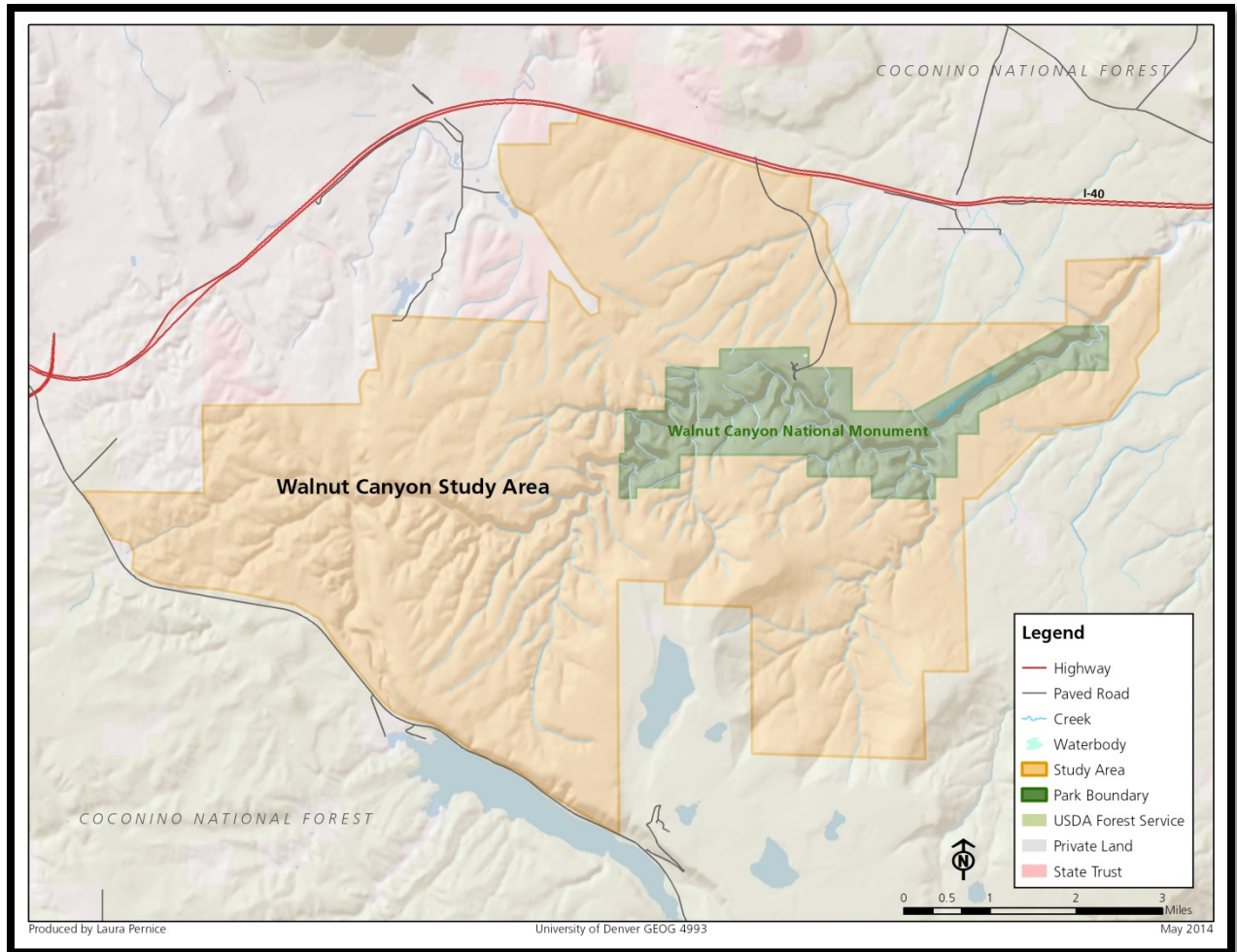
Figure 2. Walnut Canyon Study Area

Using a GIS-based model to predict locations of cultural resources can be of great use for a large landscape area that contains undiscovered sites. This is especially true in recent years due to budget restraints in both state and government agencies. Identifying specific locations of where cultural resources may exist saves time for an archaeologist when they visit a study area to ground truth for site excavation. This in turn saves money for the agency.

A GIS predictability model uses natural and cultural environmental data that is related to past peoples and their settlements to identify spatial patterns of known cultural resource sites (Clement and Kloot 2000, 2). For example, such environmental data includes distance to water, slope in elevation, and soil types. The objective of this study was to derive density and pattern information from spatial and statistical techniques used on known cultural resource sites within Walnut Canyon National Monument. Information derived based off of the known sites was then applied to areas of undiscovered sites within the Walnut Canyon Study Area to predict location and probability of their existence in relation to natural features. Results gained from the predictive model can provide insight for the National Park Service and U.S. Forest Service on their decision of management options for the Walnut Canyon Study area.

Literature Review

Archaeology and Geostatistics

Because of the varying spatial properties of archaeological data, geostatistics is a valuable tool to use for predictive modeling and spatial prediction. The paper, *Archaeology and Geostatistics*, discussed how geostatistics are a set of tools and can be used to characterize the following; spatial variation (variogram), spatial prediction (ordinary kriging), spatial simulation and spatial optimization (kriging variance). It was noted that the spatial distribution of a specific variable must be structured (as opposed to

being random) for geostatistics to be useful in the context of archaeology. Ordinary kriging (OK) is recommended for site predictability if working with raster datasets due to the method allowing the mean to vary spatially with added weights to the known variables. Lloyd et al. described how geostatistics can be a powerful tool to the 'archaeologist's took kit', but is concerned of its use due to its potential complexity.

Spatial Studies in Archaeology

Written in 1977, *Spatial Studies in Archaeology* explained how spatial analysis can be an important tool to interpret spatial distribution of archaeological sites. Keep in mind that computer-aided models were not present at this time, but the theory discussed throughout the paper relates to the same topics discussed today. An example would be how trends in data can be seen more clearly if the data are in a quantified form. Hodder continued by stating three simple examples of:

1. Differentiated between site assemblages of different reliabilities,

2. Percentages of the type present rather than just its presence or absence,

3. Plotted 'negatives' – that is contemporary sites without the cultural resource type being studied.

Hodder discussed three main issues of spatial analysis on archaeology sites; problems resulting from nature of archaeological data, problems concerning

the methods of spatial analysis, and problems in the interpretation of spatial process from spatial form.

Using GIS to Model and Predict Likely Archaeological Sites

The South Carolina Institute of Archaeology and Anthropology (SCIAA) and the Earth Sciences and Resources Institute of the University of South Carolina (Esri-USC) collaborated to develop a predictive model for likely archaeological sites using available data sources. The objective was to provide an initial dataset that management decisions can be based upon for future planning efforts. Predictive modeling was shown in this paper by identifying where cultural resources were located. It was noted how prehistoric peoples were closely tied to their natural and cultural environment. Clement et al. listed data types to be examined for modeling and included; soils, transportation systems, distance to water, and slope. Outcomes of this study spatially showed different zones of high probability where cultural resources may occur based off of known sites and their significance (categorized as level 1, 2, and 3). The issue of data quality and scale of data was discussed by stating areas where data was missing had the potential to skew the end results. It was mentioned that more detailed results could have been derived from the model if smaller distance contour lines was used within the study area.

A GIS Approach for Predicting Prehistoric Site Locations

Kuiper and Wescott's paper, *A GIS Approach for Predicting Prehistoric Site Locations*, discussed how predictability modeling for cultural resource sites is becoming increasingly popular. Environmental variables that influenced activities of the past inhabitants were used to produce and analyze the spatial location of those variables. Their study consisted of using 500 known sites in the Upper Chesapeake Bay region to identify high-potential areas for unknown sites in an unsurveyed area of 39,000 acres. With combination of the known sites and known environmental factors, outputs resulted in GIS layers representing the spatial distribution of cultural resources that matched those of the input data layers. Descriptive statistical analysis was also used for their study to determine the most significant environmental layers to be used for the model input. It was determined to not use many of the original GIS datasets due to them not being statistically significant.

It was concluded that many environmental variables associated with the known cultural resource sites were well defined and therefore the model produced meaningful results. It is important to note that predictability modeling results can be achieved with available data even if the logistic regression requirements cannot be met (Kuiper and Wescott 1999, 8). The issue described focuses on how results came from a model, and even though this type of study provides priority areas for evaluation, ground truthing and

surveying must take place after the predictability study for complete and accurate information.

Archaeological Predictive Model, U.S. 301 Project Development

The Delaware Department of Transportation wrote the paper, *Archaeological Predictive Model, U.S. 301 Project Development*, which discussed the benefit of using an empirical approach for a predictive model which was based on low-order generalizations of environmental observations. An example would be generalizing that sites are found within 300 feet of water due in part to the cultural landscape. It was noted that this approach receives greater attention from archaeologists who work in the United States. The deductive approach focuses on the idea that sites are distributed non-randomly because of how humans select locations of settlements based on their conscious decision of what best suits their physical and social needs such as needing food, water, and shelter for survival. An issue with this approach is defining archaeological site types that can be related to hunter and gatherer adaptations.

GIS was chosen as a tool to be used for modeling in this study because of the fast and convenient ways spatial data can be analyzed in a large size study area. The model was created to be able to use the wide variety of environmental data that currently exists in GIS format at a much finer spatial scale resolution. The cell size chosen was 10 meters and results were based off of the fine spatial resolution.

GIS and Archaeological Site Location Modeling

The introduction of *GIS and Archaeological Site Location Modeling* discussed how cultural resource predictability modeling can be done with ease due to the readily available digital data and GIS software applications. It also covers how current cultural resource modeling efforts have been beneficial for federal, state, and local agencies by the collation and standardization of archaeology within computer databases. For example, cultural resource data can be categorized by point, line, or polygon features depending upon its geometry and spatial location. Based off of the standards, attribute or table information associated with each geometry type is similar and contains well organized information. This makes site location modeling consistent throughout different study area locations.

Three sections of the book covered issues associated with predictability modeling. They were; theoretical and methodological issues, issues of scale, and quantitative and methodological issues. Theoretical and methodological issues related to how cultural resource data can be statistically analyzed and reported out. The issue of scale is an important factor to consider when performing a site location model because pattern and density analysis results will differ depending on how large or small of an area is being looked at. The book noted how it is important to fully understand the study area and surrounding environmental variables that are considered to be the main drivers of the site location model.

Between the Lines: the Role of GIS-based Predictive Modeling in the Interpretation of Extensive Survey Data

The article, *Between the Lines: the Role of GIS-based Predictive Modeling in the Interpretation of Extensive Survey Data*, covered in extensive detail how predictive modeling of culture resources explores relationships within the survey data and other landscape indices. There was a discussion on how surveying takes time and lots of money to obtain total coverage by field walking or ground truthing an area. Predictive modeling helps this problem by identifying potential areas of cultural resource sites in which subject professionals can study to see if in fact, it would be a high-potential area. Discussion in the multiple regression model sections described how the choice of the dependent variable may cause lack of success for the overall predictability model. Variables added to the model should be chosen with high levels of accuracy based off of the study area.

Case Studies in Archaeological Predictive Modeling: The hidden reserve. Predictive modeling of buried archaeological sites in the Tricastin-Valdaine region (Middle Rhone Valley, France)

The case study of *Archaeological Predictive Modeling: The hidden reserve. Predictive modeling of buried archaeological sites* performed by Verhagen and Berger focuses on finding the relation of site location to landscape features within the Tricastin-Valdaine region of France. The known sites were overlaid with known landscape features and were then subjected

to a quantitative analysis. During the analysis, distribution patterns were identified which could also be considered inductive modeling. An important aspect to consider when performing a predictability model is to understand that it is equally important to identify areas where there are no cultural resource sites. This concept brings more meaning to the statistical analysis and results derived from it. An issue discussed in this case study relates to how results of the predictive model may only identify visible sites. When analyzing known cultural resources, it is important to recognize if they are visible or non-visible. Separate models with different environmental variables may need to be performed to work around this issue.

To identify if statistical significance exists within the archaeological dataset, the X^2 test was applied to see if there were any statistically significant patterns between the location of the sites and map units. It was determined that the sample size limited meaningful results which led the archaeological data to then be divided into different categories in which the X^2 test could be applied. It was determined that specific site types showed statistical significance at 99.9% probability of being present within majority of the taphonomic units or environmental features.

Modelling Erosion and Archaeological Potential using GIS

The paper, *Modelling Erosion and Archaeological Potential using GIS*, discussed how an archaeological predictive model showed the locations of known sites to identify a spatial pattern that is primarily in relation to any

environmental variables. This type of inductive modeling has been the model of choice over deductive modeling due to its relative ease of production and performance. This paper discussed two main areas of concern with regards to the archaeological predictability model. The first was quality of the data, such as the DEM used and contour lines derived from it. If detailed contour lines are not available then it will be difficult to pinpoint areas of specific elevation. The second issue was quality of the results. The need for field testing from what the model produced is important because it will provide the highest level of test for the reliability of the model. With field testing, a detailed site visit can evaluate the model results for any future refinements. Even though these are areas of concern when performing a predictability analysis, this paper states that it is still a valuable tool to be used.

A Predictive Probabilistic Model of Village Site Location within the Santa Ynez Valley, California.

The objective of the study, *A Predictive Probabilistic Model of Village Site Location within the Santa Ynez Valley, California*, was to test hypotheses based off of environmental factors that influenced settlement patterns. Maps were then created to identify locations of the village site locations and show probable locations of where archaeological sites occur. Environmental datasets included in this study consisted of; hydrography, slope, and habitat areas. The Weights of Evidence method was used to portray different levels of influence that each of the environmental factors had on settlement

distribution. It is discussed in this paper that an advantage of the weights of evidence method is that the weights and confidence statistics can be easily understood and interpreted. For example, positive statistical readings show higher concentration levels of cultural resource sites, whereas lower statistical readings show lower concentrations. Results produced from this study showed specific areas where village sites are likely to occur, which in this case would be locations with less than 15 degrees slope, within 200 meters of streams, and areas with high diversity of habitat types.

Study Design and Implementation

Overview

As what was previously learned through the literature review, it can be said with confidence that historic and prehistoric peoples were closely tied to their surrounding environmental features. This in turn identifies areas where they chose their site location for surviving. Understanding what these environmental factors are and determining specific characteristics about them are crucial factors to consider when performing the predictability analysis for the Walnut Canyon Study Area.

An inductive modeling approach was used for this study. The purpose of this was to learn about the physical world and how it affected the decision of where to settle of past peoples. An inductive approach is sometimes referred to as being "correlative or "data-driven" and are based exclusively on observations of known archaeological sites (Wheatley and Gillings 2002,

142). Because inductive modeling has a limited degree of validity, it can only be applied to predicting behavior of systems that are essentially known (Cellier 2003, 14). This technique is therefore overall precise in predictions if applied carefully.

The use of geostatistics is an essential application in studies that align with cultural resource location prediction. As stated earlier, environmental factors are used to identify specific locations of cultural resources and because Earth science data varies in space in time, uncertainty may become inherent of such predictions where data does not exist. Geostatistics takes the role of describing results that may be deceptive throughout a spatial analysis study or data that are considered an outcome of a random process (Lloyd and Atkison 2003, 152).

The explanations to many geospatial relationship questions rely on the ability of an individual to uncover a pattern or patterns of certain events. Uncovering these patterns can be assisted by using Spatial Point Pattern (SPP) analysis in GIS. SPP is a set of statistical techniques used to identify patterns of occurrences at point locations in spatial data. The occurrence of cultural resources is an excellent point location example of how spatial statistical methods can be used to identify patterns in the data. Using SPP analysis techniques makes it possible to determine whether or not cultural resources are more likely to be present in certain locations as well as if they are more likely to be found in clusters or at some distance from one another.

Essential SPP analysis methods to analyze these patterns are measuring spatial density and measuring how close events are to one another. Spatial density can be defined as the number of point events per unit area, or in this case, the number of cultural resources per unit area.

During the course of this study, a total of three geostatistical and spatial analysis techniques were applied which were: (1) directional distribution, (2) Kernel density, and (3) Average Nearest Neighbor. The directional distribution tool created a standard deviation ellipse which its purpose was to summarize the spatial characteristics of geographic features. These geographic features are: central tendency, dispersion, and directional trends. The Kernel density tool calculated a magnitude of cultural resources per 1 sq. mile and produced a tapered raster surface showing the density. Finally, the Average Nearest Neighbor statistical tool was used to calculate an index based on the average distance from each feature to its nearest neighboring feature (ESRI, 2014). Results derived from this tool detected five values: observed mean distance, expected mean distance, nearest neighbor index, z-score, and p-value. All values were used to classify the statistical significance of environmental features that effect the known cultural resource locations. The z-score value was the central value observed to identify if the cultural resource sites were suggestive of either clustered or dispersed spatial patterns.

Before the geostatistical and spatial analysis tools were applied, characteristics of environmental factors must be evaluated to identify cultural resources that fall within or near them. For example, the vicinity to a water source plays an important role to describe why historic and prehistoric peoples settled where they did. The same idea can be applied towards the environmental factor such as vegetation types, which will show different identifiable characteristics.

Cultural Context of this Study

This research focuses on the Sinagua who were a pre-Columbian cultural group that occupied areas between the Little Colorado River and the Salt River (between Flagstaff and Phoenix) about 1500 years ago (National Park Service, 2014). Archaeologists suggest that they lived in pit houses which were circular huts with sunken floors and had stone or wood-lined walls with adobe roofs. The Sinagua were situated in between two other power tribes; the Anasazi to the northeast and the Hohokam to the south where trade routes were created between the three tribes. Red clay pottery, in addition to corn, was a popular trade item amongst the Sinagua.

What is interesting about the Sinagua was their disappearance with no known explanation. Researchers and archaeologists are baffled by not understanding why they disappeared after hundreds of years of successful development in an area with such fantastic resources for survival. Their disappearance is known as The Great Abandonment and it is estimated that

over 5,000 Sinagua inhabitants deserted the area (National Park Service, 2014).

The Research Area

The Walnut Canyon Study Area covers 27,194 acres of federal (25,413 acres), state (2,036 acres), and private (465 acres) land surrounding Walnut Canyon National Monument near Flagstaff, Arizona. It is within the southern portion of the Colorado Plateau and ranges in elevation from 2,400 feet to 12,670 feet. The natural process of erosion has occurred in this area and has caused geologic outcrops consisting of red sandstone and white limestone to be visible. According to the Walnut Canyon Study Area report, the study area boundaries were designated to extend protection to portions of the Walnut Creek watershed and include important riparian, old growth, and endangered species habitats; protect the area from future commercial and residential development; preserve the natural scenery; reduce or eliminate motorized access; and address fire management and forest restoration (U.S. Forest Service, 2014).

Climate

The climate for the area is typically semiarid and changes throughout the year from a hot summer, a cool and dry spring and fall, and every so often a wet winter (Hansen et al. 2004, 224). The regional climate changes with elevation with temperatures ranging from near 0 degrees Fahrenheit in winter to an average of 90 degree in summer. Since 1910, climate records

have been logged for Walnut Canyon National Monument and according to the Walnut Canyon Study Area report the same data is applicable to the actual study area. The nearby San Francisco Peaks are at an elevation of around 10,000 feet and anywhere from that elevation or higher has much cooler temperatures. This means that the growing season for those locations is usually shorter.

Precipitation

Precipitation data that has been recorded for Walnut Canyon National Monument displays an annual mean average of 18.12 inches. What is unique for the study area in comparison to geographic locations of surrounding areas is that there is a bimodal precipitation pattern. This means that there is an average of 5.52 inches of precipitation in the summer season and an average of 4.93 inches in the winter. June consists of the lowest average precipitation and August receives the highest in response to monsoon weather patterns.

Hydrography

Possibly one of the most significant environmental resources that affected the locations of where historic and prehistoric people settled was the availability of fresh water. The general directional pattern of cultural resources aligns carefully with water sources within Walnut Canyon National Monument. Ease of access to fresh water sources was a fundamental challenge to maintain a permanent, year-round living status within Walnut

Canyon for the first permanent inhabitants who thrived in the area from about A.D. 600 until 1400 (National Park Service 2014).

Water flow and stream patterns within the Walnut Canyon Study Area and Walnut Canyon National Monument are controlled by the ancient tectonic activity that can be related to the Northern Arizona Seismic Belt (NASB). The USGS provides information relating to this areas tectonic activity and states that the NASB is a zone of regional seismicity activity. Faulting that was last seen resulted in significant earthquake activity in the early part of the 20th century with recorded magnitudes of 6.0 and 6.2. Because of the geologic activity, northwest to southwest directional joints cross Walnut Canyon which causes Walnut Creek and its tributaries to flow those same directions.

The major stream within the study area, Walnut Creek, is a perennial stream and flows in an east to west direction. The canyon walls twist and curve which was carved out by the stream during ancient years. The Walnut Canyon area in its entirety is an extraordinary place because of how the presence of water was abundant in a dry land. Because this stream is categorized as perennial, deep pools and mostly reliable flows made it a valuable resource to the Sinagua who once settled there.

Habitat

Hunter-gatherer societies have heavily relied on different habitat types to provide access to food and shelter. Studies based on relationships of

humans to the land have emphasized the importance of the temporal and spatial abundance of plant, animal, and mineral resources in determining site location (Neal, 2007, 66). Such studies have examined theories relating to how settlement locations are strongly affected by the need to optimize the amount of energy expended in the process of finding resources necessary for survival.

Walnut Canyon National Monument contains a diverse amount of vegetation types and ranges from low elevation grasslands to high elevation woodland and forest communities (Hansen et al. 2004, 43). The area mostly consists of woodlands and contains dense groups of trees located on the north-facing canyon walls and in the canyon bottoms. Meadow-like areas contain sparser bunches of trees, but is not completely bare. The most common tree types found within Walnut Canyon National Monument consist of ponderosa pine, Douglas-fir, Rocky Mountain juniper, willow, and narrow leaf cottonwood.

Soil types play an important role in the agricultural and farming era of the Sinagua since that was primarily how they made their living by growing corn, beans, and squash. It was vital for them to have very high yields from their crops since they needed the surplus food to survive the winter. They also traded large amounts of corn for other essential necessities for their survival.

Criteria Used for this Study

After researching the surrounding environmental factors of the Walnut Canyon Study Area, certain conclusions were drawn to use as criteria for the analysis. In addition to what was drawn in the descriptive explanations of environmental features previously stated, the availability of GIS data was also examined to make sure it exists. Based off of the descriptive explanations, proximity to water and vegetation types were the two criterions chosen for this study.

Proximity to Water

It is known that the Sinagua built their canyon settlements near a close proximity to perennial streams such as Walnut Creek. To identify a numerical distance value between settlement sites and water source, the Near tool found in the Analysis Toolbox was used. This tool determines the distance from each cultural resource feature used as the input data to the nearest spatial location of the hydrology data layer. Because the attribute table does not specify which points are to be considered settlement locations, all features within the data layer were used in the Near analysis.

A new field was populated and showed near distance values (in feet) as the output. For the purpose of this study, the average distance between cultural resource points and hydrology features, such as perennial and intermittent streams and creeks, was used. The statistics result box of the near distance field showed the mean statistic of 204 (feet). For simplicity

sake, this number was rounded down to 200 (feet) which acted as the linear distance unit input that the buffer was created on. In conclusion, the analysis included a 200 ft. buffer zone surrounding the hydrologic features.
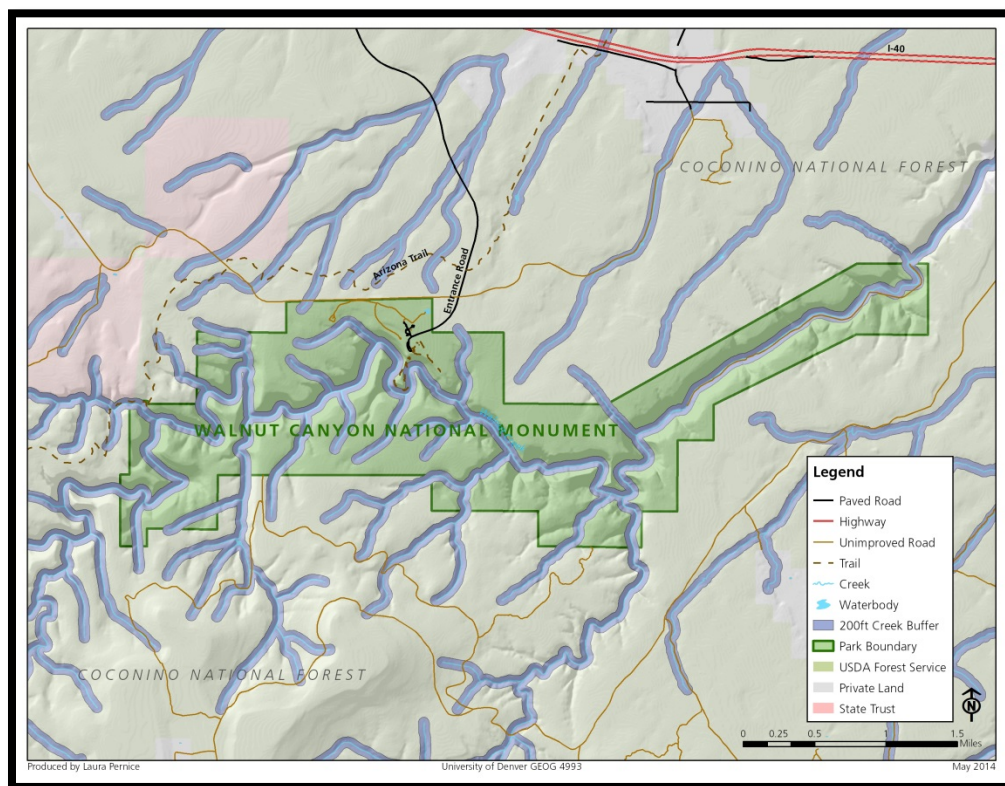
Figure 3. 200 ft. Buffer Zone Surrounding Hydrologic Features

Vegetation Types

The Sinagua were excellent farmers and needed to yield high crops for trade purposes as well as to stock up for the long, cold winters. Even though soil types are unknown, the vegetation types can convey a correlation between the two, which in turn, can help predict locations of cultural resources in the Walnut Canyon Study Area. Because a high amount of water is needed for agricultural purposes, vegetation types that fall within

the 200 ft. buffer zone were examined in relationship to known cultural resources in Walnut Canyon National Monument.
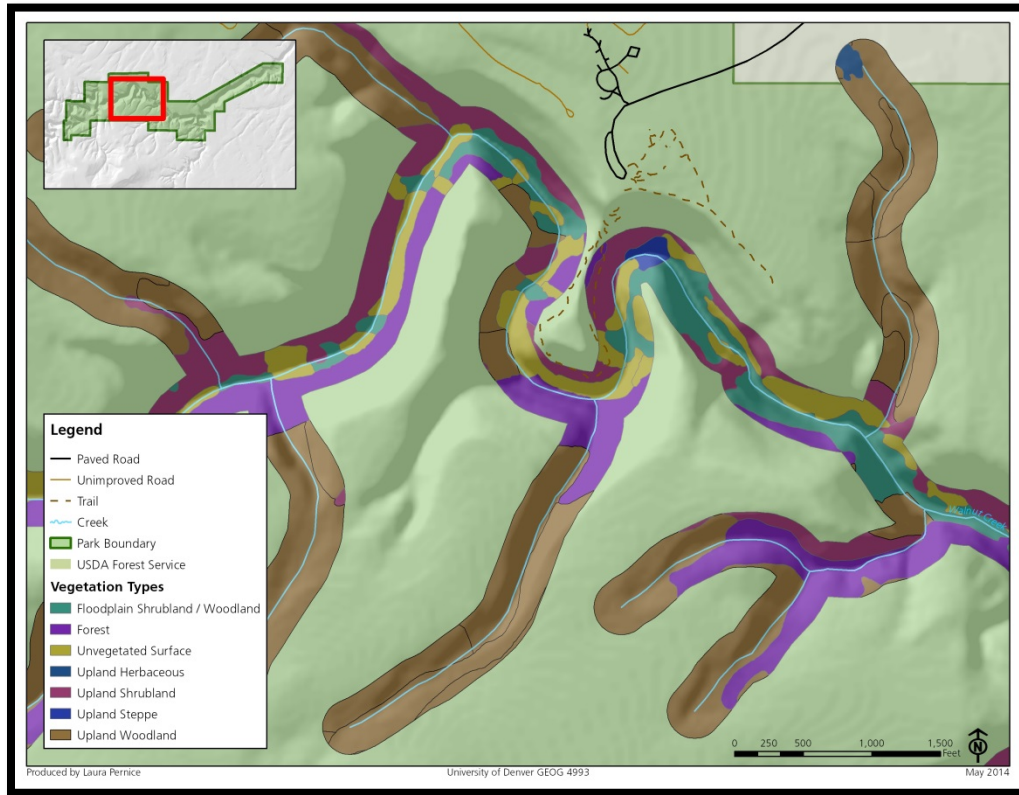
Figure 4. Vegetation Types within 200 ft. Creek Buffer Zone

Issues of Determining Criteria

According to the Walnut Canyon Study Area report, soils are a product of environmental factors that includes climate, geology, plant and animal types, and topographic characteristics such as slope and elevation. In addition, precipitation and temperature are also factors when researching soil type composition. This is clearly a complicated environmental factor, and though important when predicating cultural resource locations, soil types will not be acknowledged to use as a criteria for the predictability model.

Another issue as to why soil type data will not be used is because the dataset does not currently exist for Walnut Canyon National Monument. All soil type GIS data for National Parks are produced by the Natural Resource Inventory and Monitoring, Soil Resources Inventory program of the National Park Service. According to their update identified on the Integrated Resource Management Applications (IRMA) portal, a final dataset is still in the process of being completed with an unknown timeframe.

An issue involving vegetation data is the idea that it is extremely difficult to reconstruct past vegetation types. This is due to the constant changing natural environment that has occurred for several thousand years since the Sinagua people have occupied the Walnut Canyon area. Man made changes can also alter the natural environment by carrying out land clearing practices to support agricultural as well as the introduction of poor grazing techniques. These factors reduce the ability of the land to resist erosion, which in turn, increases the volume and speed of the surrounding streams and rivers (Neal 2007, 68).

Because the soil type data doesn't exist, the vegetation type data was chosen as an environmental factor criterion for the analysis. Due to the difficultly of reconstructing past vegetation types and uncertainty of identifying alike types from past to present, the highest level of physical classification was used. This technique was chosen because the higher level

classification types would have less percentage of change of vegetation types compared to more detailed assigned types.

Data Used for this Study

Data used for this study consisted of four vector layers and one raster layer. The cultural resources and park boundary layer were obtained from the National Park Service. The park boundary was last updated in 2010 and the cultural resources layer has an unknown date of when it was last updated. The streams layer was downloaded from the USGS National Hydrography Dataset and was last updated in 2012. The vegetation layer was also gathered from the USGS through their biological resources division and has an unknown of last update. The raster elevation layer was downloaded from the USGS National Map viewer as a DEM and was converted to a hillshade raster data layer. This layer was last updated in 2013. All layers used for this analysis were projected to coordinate system NAD83 UTM Zone 12N. Table 1 below summarizes information about each layer.

Table 1. Data Sources used for Analysis

Name	Source	Coordinate System	Last Updated
Cultural Resources	National Park Service	NAD83 UTM Zone 12N	unknown
Park Boundary	National Park Service	NAD83 UTM Zone 12N	2010
Streams	USGS NHD (National Hydrography Dataset)	NAD83 UTM Zone 12N	2012
Elevation	USGS National Map	NAD83 UTM Zone	2013

	Viewer	12N	
Vegetation	USGS/BRD (Biological Resources Division)	NAD83 UTM Zone 12N	unknown

Methodology

The criteria of environmental factors that were derived from the descriptive information found in the research area section above were overlaid with the known cultural resources located within Walnut Canyon National Monument. Statistical and spatial analysis techniques were applied and results from the final output of the predictive model was then applied to the Walnut Canyon Study Area to predict locations of unknown cultural resources.

Based off of the descriptive findings, it is known that the likelihood that cultural resources will fall within 200 feet of a stream is high. The first step of the analysis consisted of creating a 200 foot buffer using the buffer tool located in the Analysis Tools/Proximity toolbox. Next, cultural resource features that were within the 200 foot buffer were extracted. Features within the 200 foot buffer were then selected individually by subtype and a new point feature class was created showing the four cultural resource subtypes independently of each other. Table 2 shows the percentage of each cultural resource subtype that falls within the 200 foot buffer. Then, the geostatistical and spatial analysis methods were applied.

The first step of the geostatistical and spatial analysis was to create a directional distribution ellipse for each of the cultural resource subtypes

which are shown in figure 5. The purpose of this is to visually summarize the central tendency, dispersion, and any directional trends of the cultural resource data. The Kernel density spatial analysis tool was then applied and each Kernel output layer showed the average density of cultural resources per 1 square mile. Results of the Kernel density analysis are shown in figure 7. The final step was to use the average nearest neighbor spatial statistical tool to calculate a nearest neighbor index based on the average distance from each feature to its nearest neighboring feature. By doing so, a z-score was produced which classified the data to be of statistical significance. It also identified if the distribution was clustered, random, or dispersed. The report of each of the nearest neighbor results per cultural resource subtype are shown in figure 9.

The descriptive findings for the vegetation criterion indicated that the high level classification descriptions will be used. It was also indicated that the focus of the vegetation analysis should be within the same 200 foot buffer because of the relationship between fresh water and agricultural needs. To do so, the vegetation layer was clipped to the 200 foot buffer to only show vegetation types that are within the buffered zone. During this stage, nothing needed to be done with the cultural resource data because the original extracted points fall within the new vegetation boundary which is the same as the buffer zone.

The next step consisted of identifying which vegetation types had the most cultural resources located within them. This was completed by individually selecting each vegetation type classification and creating a layer from that selected feature. From there, the select by location tool was used to identify how many cultural resources fell within each of the vegetation types. Table 3 shows each vegetation type and number of cultural resources it contains. Only two of the vegetation types were chosen to be used for remainder of the analysis because of the higher amount of cultural resource points located within them. By doing so, more meaningful results will be derived from the analysis. At this time, the cultural resource point features were selected that fell within each of the two chosen vegetation types which were upland shrub land and upland woodland.

The geostatistical and spatial analysis techniques that were used with the stream data layer were the same techniques applied towards the two vegetation types. As a reminder, a directional distribution ellipse was created, then the Kernel density tool was applied, and finally the average nearest neighbor tool was used to identify statistical significance. This segment of the study did not break out the cultural resource types into the four different subtypes. Instead, the cultural resource data was analyzed in its entirety that fell within each of the two vegetation types. The purpose of this was to identify patterns or densities in a larger aspect to see if

differences arose between the subtypes or the cultural resource features as a whole.

Results

The results section describes each of the geostatistical or the spatial analysis techniques by starting first with findings from the stream criteria and then discussing results from the vegetation criteria. The reason for doing so is to be able to compare and contrast the results between criteria and cultural resource subtype more fluidly. Later in the results, descriptions of areas within the Walnut Canyon Study Area will be defined to where there is potential for cultural resources to occur based off of the predictability model.

As shown in Table 2, 73 percent of cultural resources located within the 200 foot buffer are subtype categorized as site and contained a total count of 276. Cultural resource subtype of features consisted of 11 percent of the total with a count 44, isolated objects consisted of 12 percent with a count of 46, and finally, the other subtype cultural resource category consisted of only 4 percent with a total count of 15. This clearly shows that site subtype features are more prominent near and around streams.

Table 2. Percentage of Cultural Resource Subtypes within 200 ft. buffer

Cultural Resource Subtype	Count in 200 foot buffer	Percentage
All	381	N/A
Site	276	73
Feature	44	11
Isolated Object	46	12

Other	15	4
Total	381	100

As mentioned before, the two vegetation types used for the analysis were upland woodland and upland shrub land. The upland woodland vegetation type contained a total of 184 cultural resources and the upland shrub land type had a total of 153. The remaining vegetation types were omitted from the analysis because of the low cultural resource count which would not provide meaningful statistical results and therefore would not provide insight as to where cultural resources would be located within the Walnut Canyon Study Area.

Table 3. Vegetation Types and Cultural Resources

Vegetation Type	Cultural Resource Count
Floodplain Shrub land/Woodland	8
Forest	17
Land Use	2
Un-vegetated Surface	9
Upland Herbaceous	2
Upland Modified Shrub land	2
Upland Shrub land	153
Upland Steppe	4
Upland Woodland	184

When looking at the directional distribution ellipses, it is clear that the other subtype category is the smallest with points grouped fairly close together near the top center of WACA. The tight ellipse shows that the cultural resources are not significantly dispersed. The site subtype category ellipse represents dispersion of the points being clustered towards the middle of the boundary and runs in an east to west direction which

encompasses about half of Walnut Creek. This ellipse is the most rounded compared to the others with an 87 degree rotation. This shows that the central tendency of the cultural resources surrounds Walnut Creek. The isolated object subtype category shows the largest ellipse meaning that the central tendency and dispersion is more spread. It contains majority of WACA and runs in an east-west direction with a 79 degree rotation. The feature subtype category ellipse is the most linear and narrow with a 72 degree rotation. The direction follows Walnut Creek more tightly than the others, especially on the western side of the boundary. This represents that these features are found closest to fresh water sources such as Walnut Creek and its surrounding tributaries.
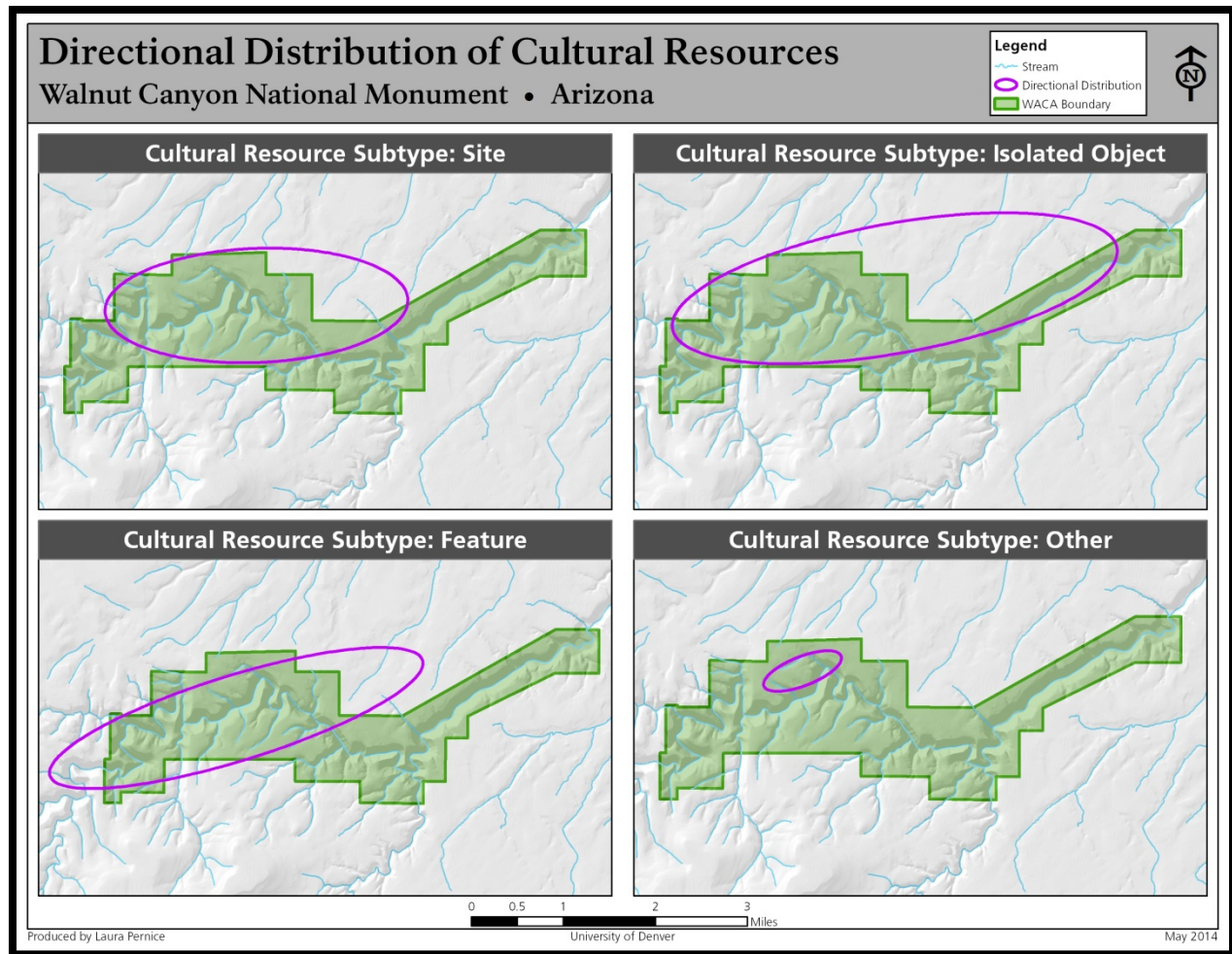
Figure 5. Directional Distribution Results for 200 ft. River Buffer

The directional ellipse for the upland woodland vegetation type shows dispersion towards the north and center section of WACA with an 80 degrees rotation. Its center covers Walnut Creek representing that cultural resources within this vegetation type are near the creek. The ellipse is fairly rounded which represents that the cultural resources are found to be more dispersed compared to what is identified in the upland shrub land vegetation type. The upland shrub land ellipse is in the same vicinity as the upland woodland but has a distinct east-west direction. The shape is more linear with an 86

degree rotation showing that cultural resources are closer together toward the middle of the ellipse.

When comparing the directional ellipses for the cultural resource subtypes and the vegetation types, it is clear that there is a relationship between the two criterions. Each show that majority of the cultural resources are to be found near the center and top center of WACA whether they are found in close vicinity to fresh water sources or in shrub land or woodland vegetation types.
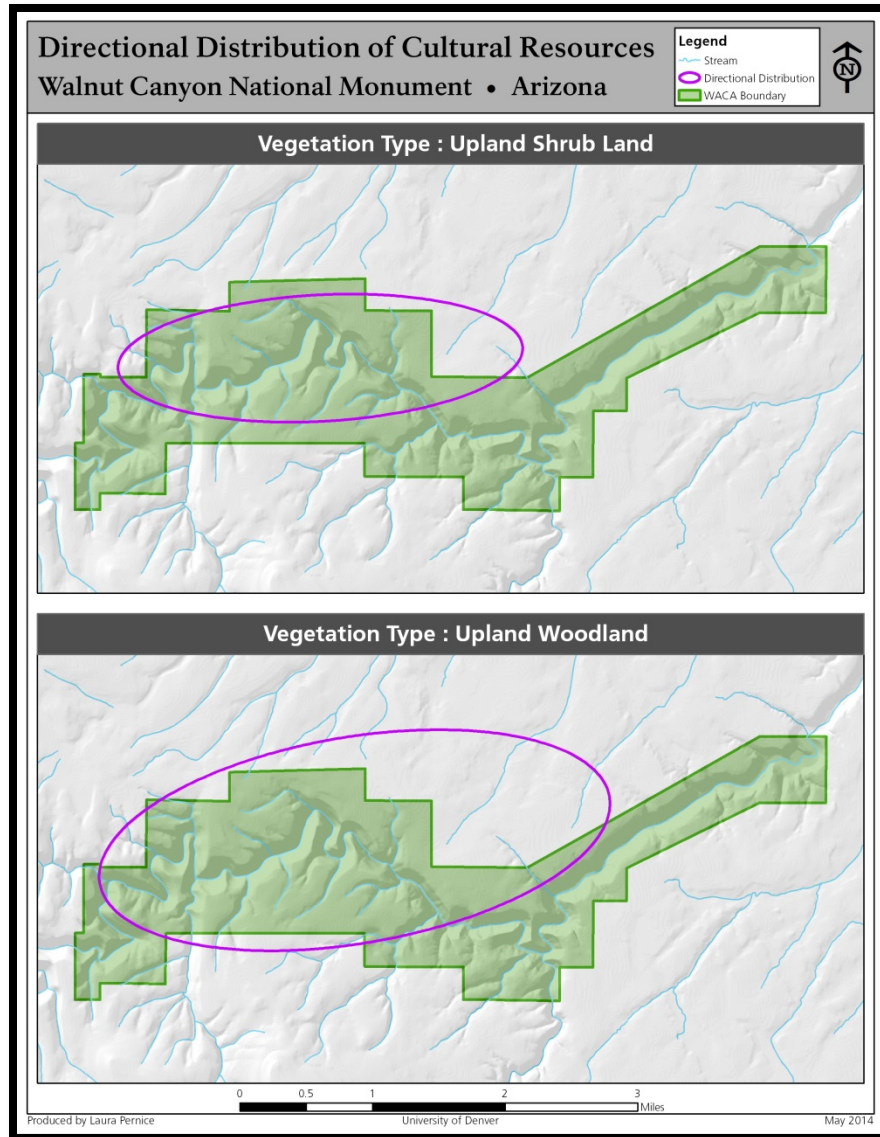
Figure 6. Directional Distribution Results for Vegetation Types

The Kernel density output layer represents the average density of cultural resource subtypes per 1 sq. mile. The site subtype category shows there is a high density of cultural resources 1,300 feet from the north-center area of WACA averaging 35.8-40.2 cultural resources per 1 sq. mile. The density begins to reduce from the high density areas, but clearly shows a close relationship to fresh water sources by the dark shaded shape

surrounding Walnut Creek. The higher density areas are the most spread within this category. The isolated object subtype category shows a high density area near the same location as the site category, but with far less of a spread. The high density at this location represents an average of 23.5-26.4 cultural resources per 1 sq. mile. The feature subtype category shows two areas of high density. The first area is very close to a smaller tributary from Walnut Creek near the north-center area of the park. The other area is located more east and is also found along a tributary of Walnut Creek. Both locations show a line of less dense areas that travel south following Walnut Creek. The high density for the feature subtype category has an average of 31.5-35.5 cultural resources per 1 sq. mile. Lastly, the other subtype category shows slightly skewed results due to it having the least amount of total features, which in turn, identifies majority of these resources all being of high density with an average of 21.9-24.7 cultural resources per 1 sq. mile. These density areas are located close to a tributary located in the north-center of WACA.
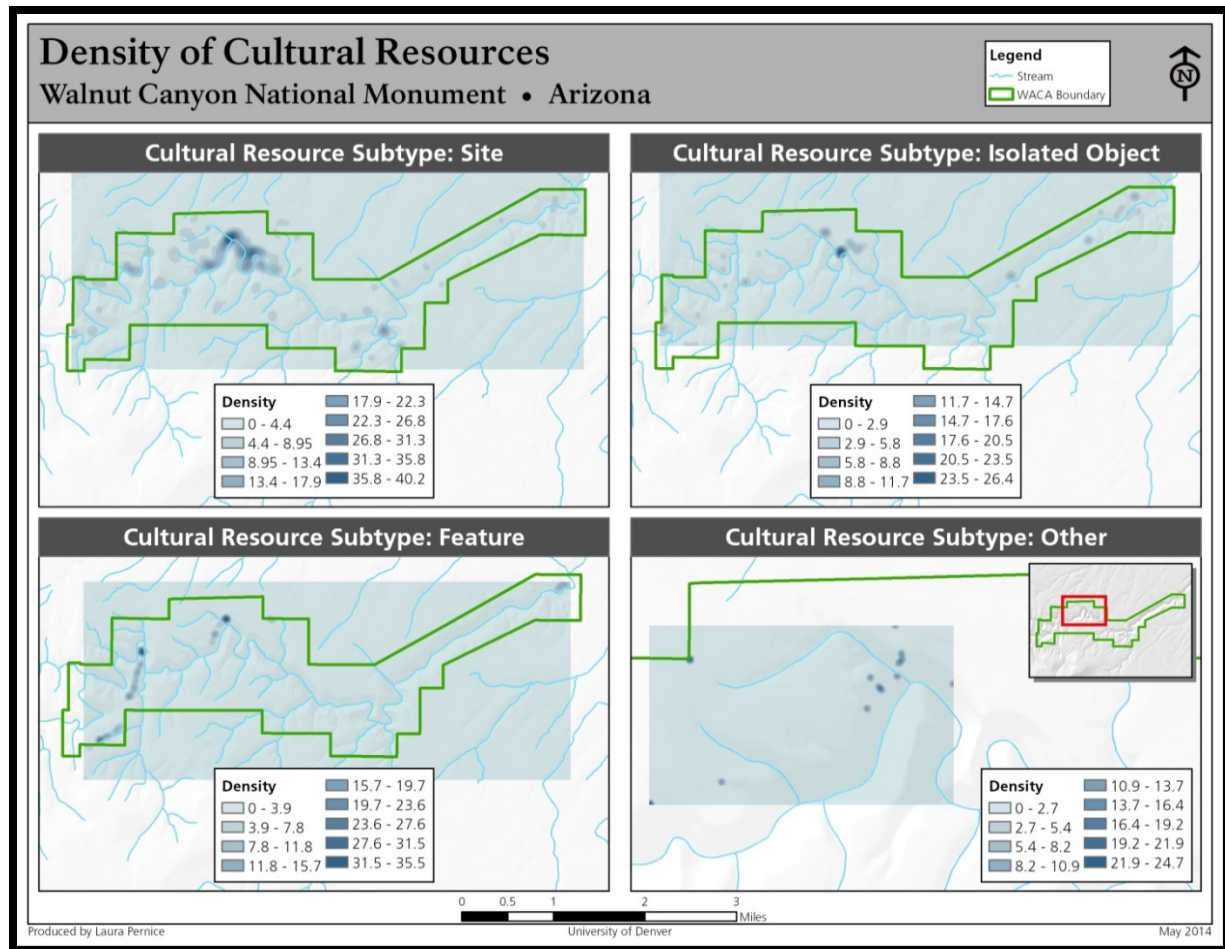
Figure 7. Kernel Density Results for 200 ft. River Buffer

The Kernel density results for the upland woodland vegetation types shows numerous areas of high density that are along the top of the canyon walls and in close vicinity to fresh water sources of both Walnut Canyon and its tributaries. The high density areas have an average of 12.2-13.6 cultural resources per 1 sq. mile. Less dense areas are towards the top of WACA where the terrain begins to level out. Majority of the less dense areas are significantly spread within that location. The upland shrub land vegetation type shows high density areas in two prominent locations near the north-center of WACA. These high density locations have an average of 43.0-48.2

cultural resources per 1 sq. mile. This category also shows the less dense areas are situated closely to the high density areas along the canyon wall with not much of a spread.
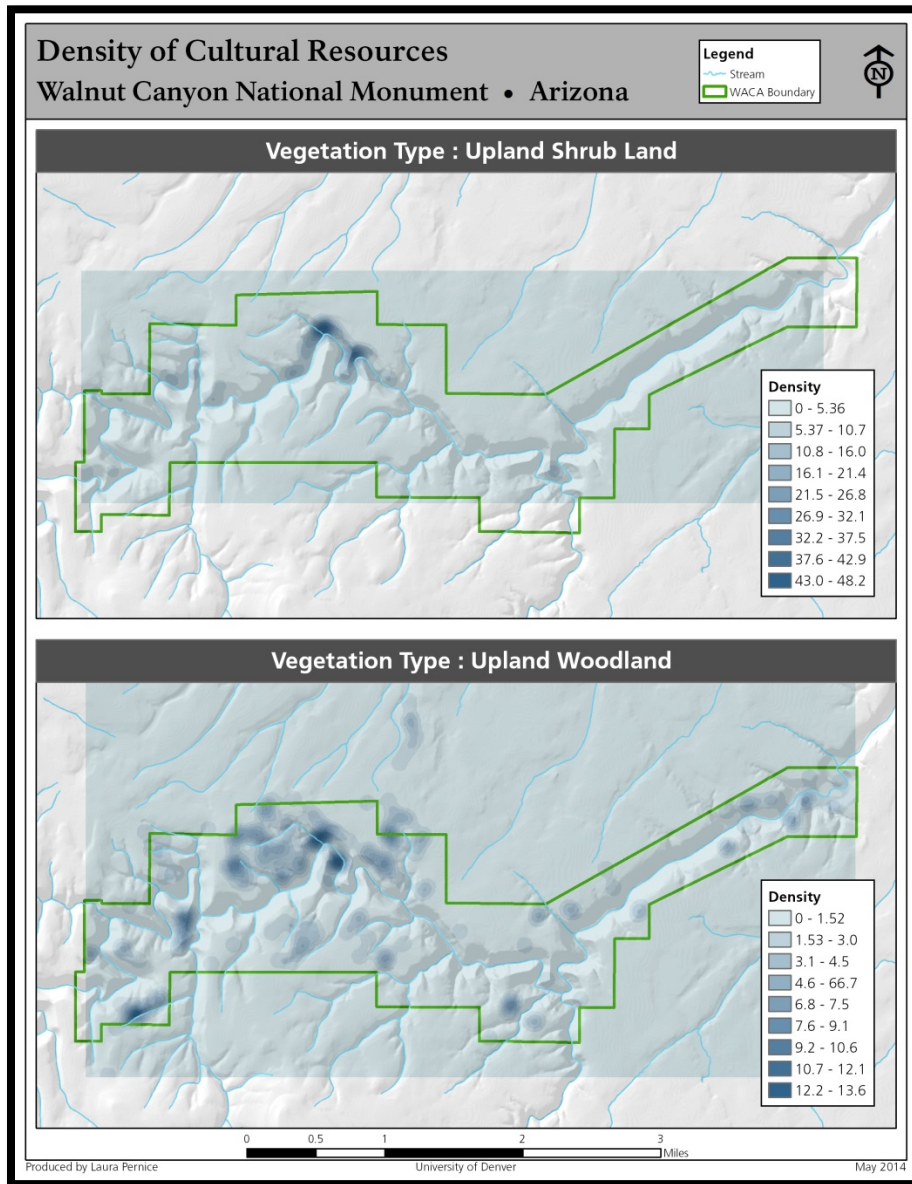

Figure 8. Kernel Density Results for Vegetation Types

The goal of the Average Nearest Neighbor statistic is to quantify the distance between each of the cultural resource points in the pattern. The

results tell us the dispersion of the pattern and if it is clustered, random, or dispersed as well as the statistical significance of the spatial clustering.

Each of the subtype categories produced a low level z-score which represents that there is less than a 1% chance that the clustered patterns are due to random chance. These low levels also show that each pattern is considered a highly clustered point pattern. The same holds true for the z-scores of cultural resources found within the vegetation types. The upland woodland produced a z-score of -13.63 and the upland shrub land produced a z-score of -17.3. Table 4 identifies each cultural resource type and its associated z-score value.

Table 4. Z-score of Cultural Resource Subtypes

Cultural Resource Subtype	z-score	Statistical Significance
Site	-16.818	Significant
Isolated Object	-7.864	Significant
Feature	-10.174	Significant
Other	-2.971	Significant

Figure 9 displays the statistical significance of cultural resources based off of each subtype category within the 200 foot river buffer. The graphics shown are report file results that are produced from the Average Nearest Neighbor tool that is located within the spatial statistics toolbox.

Figure 9. Average Nearest Neighbor Results for 200 foot River Buffer

Figure 10 below displays the statistical significance of cultural resources based off of the vegetation types used for the analysis.
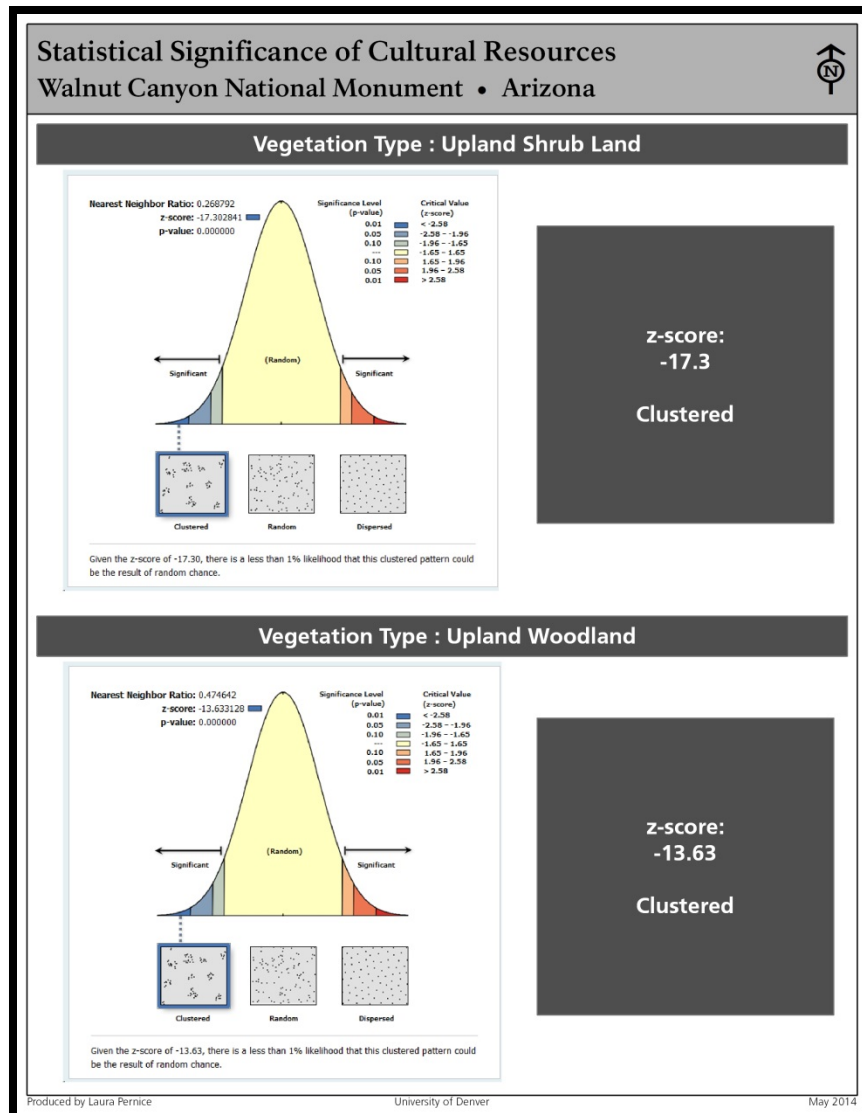
Figure 10. Average Nearest Neighbor Results for Vegetation Types

After analyzing the results based off of known cultural resource sites located within Walnut Canyon National Monument, many conclusions can be drawn that are applicable to the Walnut Canyon Study Area. Based off of the Average Nearest Neighbor results, cultural resources will be found in highly clustered patterns throughout the study area. These clustered patterns are not due by chance which signifies that the environmental factors designate specific locations of where the unknown cultural resources can be located.

The directional distribution results indicate that the spread of cultural resources follows closely to fresh water sources. This can be seen by the shape of each ellipse being elongated and following the direction of Walnut Creek and surrounding tributaries. Ends of the ellipse that begin to level to a point specifies that the distribution of cultural resources start to diminish and are not centrally dispersed. It is important to keep in mind that the distribution of the different subtypes of cultural resource varies slightly and that some resources may be present at a greater distance from the fresh water source or specific vegetation types. Archaeologists must be exceptionally knowledgeable about the types of cultural resources when out in the field because of the variations of distributions.

The Kernel density results show that cultural resources are likely to be located in upland woodland types within a large spread area. Within the upland shrub land vegetation type, the density of cultural resources will be more compact in highly dense areas. Within either upland woodland vegetation or upland shrub land vegetation, high density areas will still be within a close vicinity to fresh water sources. By looking at the densities per resource subtype, it can be concluded that the density of the site subtype category is the highest ranging from 35.8-40.2 cultural resources per 1 sq. mile and the other subtype category has the lowest density with a range of 21.9-24.7 cultural resources per 1 sq. mile. Results of this analysis clearly

show that a fresh water source plays an important role to location of cultural resources.

Discussion

Results derived from this predictability model can be used as a decision making tool for planning departments and personnel who are involved in the Walnut Canyon Study or any type of land-use planning project. This type of analysis provides a cost-effective way to identify areas where potential cultural resources may be present by saving time, effort, and money. Though modeling does not replace the significant and mandatory need for intensive archaeological surveying, it provides guidance on areas of where to begin.

The National Park Service is continually working to determine the National Significance of archaeological sites. Several actions are taken for determinations and one way is to observe relationships of cultural resources and compare patterns in those relationships to similar patterns seen elsewhere (National Park Service, 2014). Though the predictability model as a whole may not be useful for National Significance determination, the individual geostatistical and spatial analysis techniques used in this study could be.

Physical artifacts and site locations are needed to reconstruct and build models of prehistory which are interpreted to tell stories of the past and to explain changes in the environment, society, and cultures over time. By

studying cultural resources, in return, is the study of past human activities from both a scientific and humanistic perspective. The scientific view focuses on questions as to how and why people interacted with their environment while the humanistic view attempts to find meaning (emotion and experience) through cultural resources. Both of which are of great importance to continue the learning and understanding of our past.

Areas for Further Research

One area for further research is applying advanced technical methods to the predictability model such as the weights of evidence method. This method consists of using a set of exploration datasets and a hypothesis stating "this location is favorable for occurrence of X" with weights added to the datasets (Cellier 2005, 8). The hypothesis is then tested numerous times until all locations within the map have been evaluated. This could be applicable to site prediction modeling in which each environmental factor would be weighted, and then tested to see if specific areas contain the factor more often. This method is suitable for multi-criteria decision making which directly aligns with a predictability model.

Another research area that could be further explored within site prediction modeling is allocating significant levels to the cultural resource data. For example, a data layer could be divided into three ranked levels based off of its significance that relates to general information, environment and location, characteristics, and components of the site. This additional

technique would only be possible if enough attribute information exists within the cultural resource data layer. Identifying patterns of the different significant levels can provide useful information to land-use managers to help with prioritizing areas to survey first.

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